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Visual span and change detection in soccer: An expertise study

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There is evidence to suggest that sports experts are able to extract more perceptual information from a single fixation than novices when exposed to meaningful tasks that are specific to their field of expertise. In particular, Reingold et al. (2001) showed that chess experts use a larger visual span including fewer fixations when compared to their less skilled counterparts. The aim of the present study was to examine whether also in a more complex environment, namely soccer, skilled players use a larger visual span and fewer fixations than less skilled players when attempting to recognise players' positions. To this end, we combined the gaze-contingent window technique with the change detection paradigm. Results seem to suggest that skilled soccer players do not use a larger visual span than less skilled players. However, skilled soccer players showed significantly fewer fixations of longer duration than their less skilled counterparts, supporting the notion that experts may extract more information from a single glance.

Keywords: Information pick-up; Perceptual skills; Recognition; Visual span.

Since the pioneering work of Chase and Simon (1973a), it is argued that perceptual and memory expertise is task-specific, and not a general ability that entails superior or unique structures of memory processes. In particular, Chase and Simon (1973a, 1973b) expanded on the work by de Groot (1946/1978), showing that chess masters were better able to memorise and reproduce chess configurations than less skilled chess players when exposed to structured chess positions for a few seconds. However, this superiority vanished

when random chess configurations were presented. Chase and Simon concluded that chess expertise relies on the association between memorising meaningful perceptual chunks (i.e., perceptual encoding of several chess pieces) and creating appropriate next moves (i.e., effective problem solving). Meaningfulness refers to the semantic properties of the configurations that are familiar to the chess masters who are supposed to have a vocabulary of approximately 50,000 to 100,000 chunks (see Simon & Gilmarin, 1973).

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In order to examine whether the generation of meaningful chunks is accompanied by a perceptual advantage in experts, Reingold, Charness, Pomplun, and Stampe (2001) recorded eye-movement behaviours in expert and novice chess players. In accordance with the notion that the expert's superiority is based on different perceptual encoding, Reingold et al. predicted that experts would use a larger visual span in structured chess configurations. That is, experts were expected to use fewer fixations while processing more information from a broader portion of the chess board. To test their predictions, Reingold and colleagues used the gaze-contingent window technique (cf. McConkie & Rayner, 1975). In the gaze-contingent window paradigm visual information is limited to a "window" that is continually adjusted to the gaze position. Consequently, all information not captured by the window is currently invisible to the observer (for an overview, see Rayner, 1998). By systematically decreasing the size of the window after successful trials, the smallest possible visual span that did not have detrimental effects on performance was measured.

In addition, Reingold et al. (2001) combined the gaze-contingent window technique with a flicker paradigm (e.g., Rensink, O'Regan, & Clark, 1997; Werner & Thies, 2000). Based on the flicker paradigm, Werner and Thies (2000) provided evidence that expertise in a specific domain, in their study American football, increases the observer's sensitivity to detect changes in meaningful domain-related images. Accordingly, in the study by Reingold and colleagues, the flicker paradigm required participants to detect as quickly as possible a change between two chess configurations that only differed in the positioning of one chess piece. The two configurations alternated repeatedly until the participant indicated to have detected the change. The change detection task itself did not require any chess experience or knowledge. Reingold et al. predicted that expert chess players would outperform their less skilled counterparts in the change detection task and further hypothesised that this would be accompanied by larger visual spans in experts when exposed to structured chess configurations. Indeed, results confirmed that experts used a larger visual span including fewer fixations than less skilled chess players. Moreover, the experts showed superior performances in the change detection task when presented with meaningful configurations. However, this superiority disappeared in unstructured chess scenarios. To-

gether these findings provide strong evidence to suggest that experts are able to extract more perceptual information from a single fixation than novices when exposed to meaningful tasks that are specific to their field of expertise.

The aim of the present study was to examine whether the same effects can be found in a more dynamic and complex environment, namely in soccer. Having said this, the current study expands on the work by Reingold et al. (2001) in several ways. First, whereas previous work in chess dealt with the recognition of structured and unstructured chess configurations on a structured surface (i.e., the chess board consist of 64 squares and thus systematically predefines the positioning of chess pieces), we aimed to use more "unstructured" soccer situations (i.e., positions are less predefined and vary more than chess figures). Second, we sought to investigate whether—as part of their expertise—skilled soccer players use a larger visual span and fewer fixations when compared to their less skilled counterparts when attempting to recognise players' positions. Sport-related eye-movement research seems to indicate that expert players use fewer fixations of longer durations than less skilled players (for an overview see Mann, Williams, Ward, & Janelle, 2007). This is in accordance with the notion that experts seem to show an extended quiet-eye (i.e., longer fixation) period (see Vickers, 1996). In sum, this research seems to suggest that experts are able to exhibit more relevant information from a single glance.

In the current paper, similar to Reingold et al. (2001), we apply the combination of the gaze-contingent window technique and a change detection task based on stimuli (i.e., photos) taken from original professional soccer matches. In keeping with Reingold et al., we predicted that expert players would use a larger visual span and lesser fixations than less skilled players when asked to detect a change in two repeatedly alternating stimuli, showing the same situation that differs in one position. In addition, we used structured and unstructured situations to examine whether these effects are specific to meaningful situations, but not to unspecific and meaningless game situations (see also Reingold et al.). For both unstructured (i.e., meaningless) situations and an additional symbolic situation condition, we predicted the recognition superiority of experts to vanish.

METHOD

Participants

A total of 56 male participants took part in the experiment; 21 skilled soccer players ($M = 26.0$ years, $SD = 4.4$), 21 less skilled players ($M = 25.8$ years, $SD = 2.2$), and 14 control participants ($M = 24.8$ years, $SD = 2.8$) participated voluntarily in the change detection task. Both the skilled (playing experience: $M = 21.1$ years, $SD = 3.8$) and the less skilled players (playing experience: $M = 17.9$, $SD = 3.5$) had acquired extensive soccer playing experience. Nevertheless, the skilled players had reached semiprofessional levels, and the less skilled players performed on a recreational level. The control group had no active soccer experience.¹ All participants had normal or corrected-to-normal vision. Informed consent was obtained prior to participation.

Stimulus production

The stimulus displays showed soccer situations, each presenting 10 to 17 players (i.e., between five and nine players from each team). We selected offensive situations (i.e., the attacking team is in ball possession in the half of their opponents, see Figure 1), defensive situations (i.e., the defending team is in ball possession and trying to open the game in their own half), and unstructured situations (i.e., the ball is out of play, and players are positioned randomly on the field such as during injuries). All situations are overview images that were presented from a side view perspective (see Figure 1).

In addition, we prepared symbolic soccer configurations that contain the tactically relevant semantics, but show these situations on an abstract level. That is, symbolic player figures (either blue or red) that are typically used on tactic boards to clarify instructions about team tactics were presented. For each of the four stimulus categories (i.e., offensive, defensive, un-

structured, and symbolic stimuli) 96 different situations were chosen, resulting in a total of 384 distinct scenes.

We further manipulated each stimulus display by mirroring the running direction of one single player by 180 degrees, using Adobe Photoshop CS2. For example, if the player seemed to be running towards the goal in the original image, in the manipulated stimulus the same players' orientation was switched by 180 degrees, suggesting that he was running into the opposite direction. The manipulation areas were equally balanced across the displays. While there are several options to induce change blindness (e.g., replacing a player by a different player; see Werner & Thies, 2000), we chose to manipulate the running direction because this can be considered a crucial change that also significantly alters the options for plays, and thus the meaning (i.e., the tactics) of the situation. For instance, if a defender is not trying to follow the attacker but instead running away from him, a pass to the attacker becomes much more likely. That is why we referred to these alterations as meaningful changes in the structured scenes. To compare the effects of this manipulation across the different stimuli types (i.e., structured, unstructured, and symbolic) the type of manipulation was kept constant throughout all experimental conditions.

On each trial, the original and the manipulated stimuli alternated repeatedly for 1000 ms each with a 100 ms black screen interval. The repetitions continued until the participants made a decision. The participants were required to detect the manipulated player (i.e., the manipulated position) as quickly as possible and mark the detection by pressing the spacebar. In addition, they were required to use the cursor to indicate the area they thought the manipulated player to be. The areas outside the gaze-contingent window were blurred, and thus prevented participants from picking up relevant information other than displayed in the gaze-contingent window (see Figure 1). Each stimulus and its corresponding alternation were presented once.

Eye movements

Eye movements were measured using a head-mounted EyeLink II system (SR Research). Following a nine-point calibration and validation, gaze position errors were less than 0.5° . We monitored eye movements for the purpose of

¹As watching soccer games on TV was not assessed, it cannot be ruled out that also the participants of the control group may have had some visual experience with soccer. Yet, when we recruited control participants, we only recruited students who reported to have absolutely no practical soccer experience (not even at a recreational level) or familiarity with soccer. We therefore deem it very unlikely that any of the control participants had extensive knowledge of soccer from watching games on TV.



Figure 1. Example of a stimulus with the gaze-contingent window (i.e., presented soccer situation). [To view this figure in colour, please visit the online version of this Journal.]

controlling the gaze-contingent window. In addition, we recorded the number and durations of fixations.

Procedure

On arrival, participants were welcomed and seated approximately 60 cm (23.6 inches) in front of a 17-inch screen (Iiyama Vision Master Pro 510 with 100 Hz, 720 × 560 pixels). Seat height was adjusted so that the eyes were approximately at the middle of the screen. Following instructions, participants pressed the spacebar to start the experiment (i.e., the first baseline block). Once they detected the manipulated position, they pressed the space bar as soon as possible, and indicated the target area using the cursor (via mouse).

Each baseline as well as experimental block contained 24 trials. These 24 trials consisted of six offensive, six defensive, six unstructured, and six symbolic stimuli. The different scene types were blocked within each experimental block. However, in contrast to the experimental blocks, in the baseline trials no gaze-contingent display was applied. In total participants completed 16 blocks, every fourth block presenting baseline trials (beginning with the first block). The blocked scene types (i.e., six offensive, six defensive, six

unstructured, and six symbolic stimuli) within each experimental block were presented at random. Moreover, in each block also the stimuli with their corresponding alterations were presented randomly. Detection times and response accuracies were automatically recorded by the software.

The gaze-contingent window was always centred on participants' gaze positions and consequently moved when gaze position changed. The median of the detection time of each block was used to determine the window size of the next block. The initial size of the circular gaze-contingent window was set to 300 pixels (diameter). Thus, if the median of the detection time was longer than 102% of the normative (previous) detection time then the window was increased by 30 pixels. In contrast, if the median of the detection time was shorter than the normative detection time then the size of the window was decreased by 30 pixels. Similar to Reingold et al. (2001), we accounted for changes due to fatigue and/or practice, by using four baseline measures (Blocks 1, 5, 9, and 13). Based on these measures the normative speed was updated based on three sequences of adjustments. In addition, we decreased the size adjustments after each (baseline) recomputation to 20 pixels, 15 pixels, and finally 10 pixels.

Data analysis

The mean percentage of errors was 1.01%, and there was no difference between the groups (skilled 1.3%, less skilled 0.9%, and novices 0.8%). Therefore, as performance variables only the final gaze-contingent window size and the mean detection times for the non-gaze-contingent baseline trials were analysed using two separate 3 (expertise) \times 4 (situation category) ANOVAs. Furthermore, eye-movement data, namely number of fixations and relative fixation durations, were subjected to two additional ANOVAs with group as independent variable. Effect sizes were calculated using partial eta squared values. The alpha level for significance was set at .05.

RESULTS

Performance variables

In regard to the size of the gaze-contingent window, ANOVA revealed a significant main effect for neither visual span, $F(2, 52) = 0.458$, $p > .10$, $\eta_p^2 = .017$, nor situation category, $F(3, 156) = 0.629$, $p > .10$, $\eta_p^2 = .012$. There was no interaction effect for situation category and group, $F(6, 156) = 0.39$, $p > .10$, $\eta_p^2 = .015$ (see Figure 2).

For the detection times, ANOVA revealed a significant main effect for situation category, $F(3, 156) = 52.37$, $p < .001$, $\eta_p^2 = .50$. Bonferroni post hoc comparisons revealed that structured offense

and unstructured scenes significantly differed from structured defence and symbolic situations (all $ps < .001$). Yet, there were no differences between structured offence and unstructured situations or structured defence and symbolic situations (both $ps > .1$). As illustrated in Figure 3, participants showed slower response times in structured offence and unstructured situations, whereas they detected the manipulated positions quicker in the structured defence and symbolic situations.

Yet, there was no significant main effect for group, $F(2, 52) = 2.846$, $p > .05$, $\eta_p^2 = .099$, nor did the interaction group and situation category attain significance. In addition, we analysed whether the groups differed across the baseline blocks (i.e., Blocks 1, 5, 9, and 13). ANOVA revealed a significant main effect for baseline block, $F(3, 114) = 5.52$, $p < .01$, $\eta_p^2 = .13$, indicating that in all groups detection times decreased from the first ($M = 7089.79$ ms, $SD = 1854.84$ ms) to the final block ($M = 5819.05$ ms, $SD = 1214.45$ ms). Yet, there was no main effect for group, $F(2, 38) = .02$, $p > .10$, $\eta_p^2 < .001$, nor a significant interaction between baseline block and group, $F(6, 114) = 1.73$, $p > .01$, $\eta_p^2 = .08$.

In sum, the analysis of the performance variables indicates that there were no differences between the different levels of expertise regarding either size of visual span or reaction times. However, specific situations, defense and symbolic situations respectively, facilitated detection times.

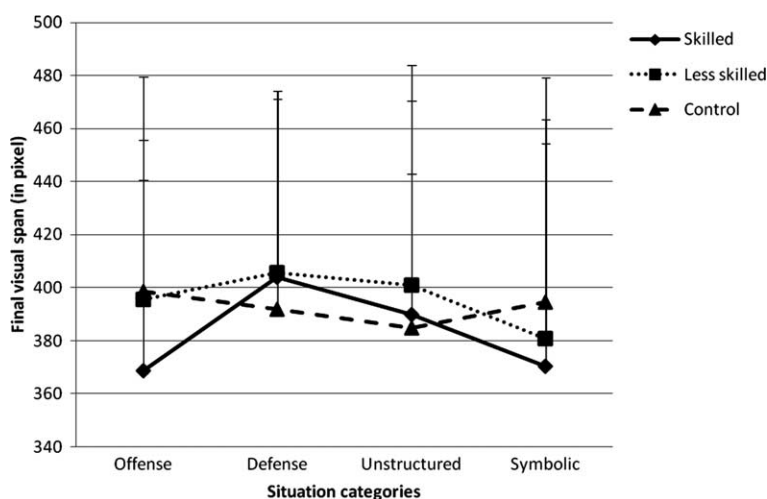


Figure 2. Final visual span (in pixel) for the three groups across the four different situation categories. Bars indicate the standard deviations (SD).

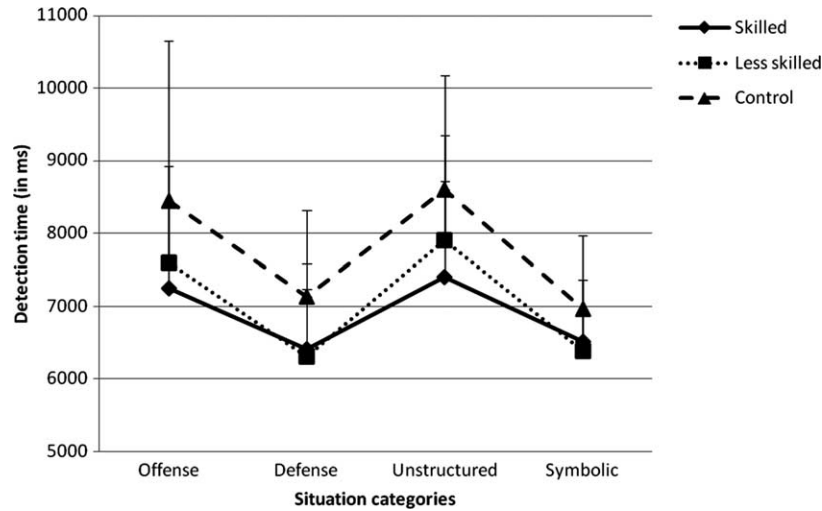


Figure 3. Detection times (in ms) for the three groups across the four different situation categories in the non-gaze-contingent baseline trials. Bars indicate the standard deviations (*SD*).

Eye-movement data

ANOVA showed that number of fixations differed significantly between the groups, $F(2, 51) = 4.75$, $p < .05$, $\eta_p^2 = .15$. Post hoc comparisons revealed that experts and less skilled players used fewer fixations than inexperienced control participants (both $ps < .05$; see Table 1).

ANOVA also revealed that fixation duration differed significantly between the three groups, $F(2, 51) = 3.26$, $p < .05$, $\eta_p^2 = .11$. Fixation duration was significantly longer in skilled soccer players when compared to the novices ($p < .05$), but the fixation durations of less skilled players did not significantly differ from those of the other two groups (see Table 1).

DISCUSSION

The aim of the present study was to examine whether the finding that experts in chess use a larger visual span including fewer fixations than less skilled players (see Reingold et al., 2001) is a more general phenomenon that may account for the superiority of experts across various sports. To

this end, we expanded on the work by Reingold and colleagues by using a more “unstructured” environment, namely situations in soccer. Similar to Reingold and colleagues, we combined the gaze-contingent window technique and the change detection paradigm. In keeping with Reingold et al. and recent research showing that elite athletes make use of fewer fixations of longer durations (e.g., Mann et al., 2007), we predicted that skilled soccer players would use a larger visual span and fewer fixations of longer durations than less skilled players when attempting to recognise players’ positions.

The results did not reveal skill-related effects on change detection performance (i.e., detection times). That is, in contrast to Reingold et al. (2001), in our study there were no differences between the different levels of expertise regarding the detection times. This unexpected finding raises questions regarding the methodological differences to Reingold et al., and consequently the theoretical impact of our findings and the implications for future research. In our view, two aspects that differed in comparison to previous studies (Reingold et al., 2001; Werner & Thies, 2000) may account for the contradictory results

TABLE 1 Mean number of fixations (*SD*) and fixation durations in ms (*SD*) for all three groups

	Number of fixations	Fixation duration
Skilled	17.45 (3.09)	477.93 (69.79)
Less skilled	17.76 (2.51)	456.55 (73.27)
Controls	20.61 (3.81)	416.82 (70.71)

and ask for further experimentation: these relate to (1) the use of dynamic versus static stimuli when aiming to simulate dynamic environments, and (2) the identification and manipulation of meaningful changes within the change detection paradigm.

With respect to the use of static (Reingold et al., 2001) or dynamic stimuli, we argue that perhaps, due to methodological constraints of the current study, skilled players could not fully apply their in-field perceptual strategies. That is, participants were presented with static slides rather than with dynamic events (e.g., videos), as typically encountered in real game situations. Thus, although the combination of the gaze-contingent window paradigm and the change detection task successfully yielded significant insights into the use of perceptual information and different visual spans across expert and novice chess players (Reingold et al., 2001), this combination may have its limitations when more dynamic environments such as soccer situations are to be examined. Recent research indeed indicates that basketball experts only outperformed their less skilled counterparts in predicting whether the presented basketball player was passing the ball or only pretending to pass it when the stimuli were presented as videoclips, but not with static slides (Sebanz & Shiffrar, 2009). Thus, skilled players may exclusively access their expertise if the situations reflect the dynamic properties that players also face in the real situation. The static slides may have been useful in chess, but for dynamic sports such as soccer with constantly (temporally and spatially) moving players, videoclips may be a more appropriate solution. Clearly, more research is needed to substantiate that the gaze-contingent window paradigm combined with video footage might be better able to capture skill-related differences in the processing of visual information from dynamic environments.

Yet, in contrast to this line of reasoning, Werner and Thies (2000) showed that observers were more sensitive to detect changes in meaningful domain-related images when presented with static American football images. However, Werner and Thies used different manipulations. As meaningful changes (i.e., semantic changes) they exchanged, for example, a moving player with a stationary player, or added a football in the action scenes. Less meaningful (i.e., nonsemantic) changes included the reversal of a cast shadow, or changing the colour of a referee's glove. These methodological differences may account for the

contradictory findings; however, more research is needed to examine why and how the manipulations seem to lead to obviously different results. Taken together, it seems that the key is that the task must be facilitated by domain related patterns. Consequently, the lack of differences in change detection performance in the current study asks for caution also when interpreting the results concerning the visual span size.

In contrast to previous findings (see Reingold et al., 2001), the results seem to suggest that skilled soccer players did not use a larger visual span when trying to recognise players' positions. Moreover, the results showed that there were no significant differences regarding visual spans across the situation categories. Yet, it needs to be acknowledged that, apart from the limitations mentioned earlier, detecting the change in the unstructured situations did not necessarily require different search patterns when compared to the structured positions. That is, as in structured situations meaningful changes were distributed across the entire displays, the difference between the two situation categories may have resulted to be minimal. Therefore, when examining the detection of meaningful changes in domain-specific situations, future studies need to first identify the likelihood and importance of the dynamic situations under investigation, and then apply this assessment to the distribution of the experimental conditions. More specifically, if specific situations in dynamic environments differ in meaningfulness, then it would be interesting to examine whether this difference in meaningfulness is associated with different gaze behaviour strategies and visual spans. This route seems promising, as researchers would match the domain-specific cognitive and perceptual experiences of skilled participants to their experimental designs, thereby gaining insights into the specificity of situations in which skilled performers apply and benefit from larger visual spans.

In addition, skilled soccer players indeed showed fewer fixations of longer durations when compared to their lesser skilled counterparts and novices. First, this indicates that gaze behaviour strategies indeed change with the accumulation of domain-specific experience (see Mann et al., 2007). Second, such skill-related differences in gaze strategies are typically thought to be functional in terms of more efficient information pick-up. Yet, although the results are in accordance with a recent meta-analysis by Mann et al. (2007), suggesting that across various sports experts seem

to apply fewer fixations of longer durations, this does not necessarily imply the use of a larger visual span. Hence, our results challenge the idea that fewer fixations of longer duration are intimately linked to larger visual spans in the perceptual processing of experts (Reingold et al., 2001). That is, although experts applied different gaze strategies than novices, these were not related to better performances (i.e., faster detection times) or larger visual spans. As already alluded to, we deem it likely that this may be due to the meaningfulness of changes. Therefore, future research needs to empirically examine under which circumstances experts' gaze strategies are linked with larger visual spans and when not. Answering this question reflects an important endeavour in the examination of skill-related differences in perceptual processing.

Here, we speculate that skilled soccer players may not necessarily be dependent on a larger visual span because they can pick up and recognise relevant and meaningful information of the positions of players from rather subtle cues (e.g., the distance between two players). More specifically, although a larger visual span provides more (peripheral) information about positions of players, perhaps skilled soccer players refrain from applying such a broad information pick-up strategy because it may inherently also carry redundant information for reading the play. There is indeed evidence to argue that skilled players seem to pick up and use rather subtle cues to read and recall the structure of play situations. First, Williams, Hodges, North, and Barton (2006) showed that it is rather specific relational information between certain key players that provide crucial information for superior recognition in soccer. Second, several studies provide evidence for the superiority of experts in picking up, for example, subtle kinematic cues when attempting to recognise and anticipate the outcome of an opponents action (e.g., Abernethy & Zawi, 2008; Huys et al., 2009; Williams, Huys, Cañal-Bruland, & Hagemann, 2009).

Moreover, due to the complexity of the situations it might be that detection of the changes needed close scrutiny, whereas the changes used in Reingold et al. (2001) were fairly large (overall shape changed) and so didn't need scrutiny, allowing a larger visual span. Alternatively, experts might have more extensive knowledge to focus on the details, and so have a slightly smaller visual span. Yet, due to the limitations and the

null effects regarding change detection performance and visual span size, more research is needed to provide more insight into the role of visual span size in expert recognition.

To conclude, we combined the gaze-contingent window paradigm and the change detection paradigm to examine whether skilled soccer players use a larger visual span and fewer fixations of longer durations than lesser skilled counterparts and novices when attempting to recognise players' positions. Results showed that indeed skilled players use fewer fixations of longer durations. However, in contrast to chess (see Reingold et al., 2001), in soccer this fixation strategy does not seem to be accompanied by larger visual spans. Future research needs to spark further methodological developments by using dynamic videoclips instead of static slides within the promising combination of the gaze-contingent window and the change detection paradigms. Such an approach may warrant significant insights into the perceptual processes underlying expert recognition in dynamic environments.

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